ADAPTABLE COMMUNICATION PROTOCOLS FOR ROBOTIC BUILDING SYSTEMS

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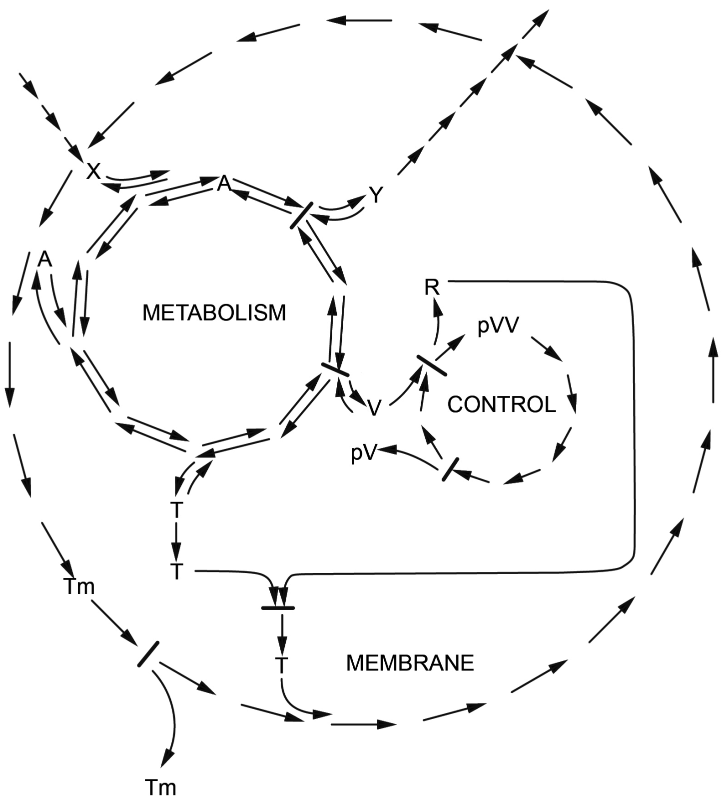


1 Reduced graphical representation of a chemoton model

ABSTRACT

This work in progress presents the framework for an information system to be used as a first step in the generation of a communication protocol for adaptable designs and adaptable constructive systems. Using the chemoton model developed by Tibor Gánti as a basic information network structure which answers some of the questions about what adaptability means in living forms; extracting the characteristics of such adaptable systems we continue to describe how this information network can be applied in the state of contemporary adaptable architecture and it´s design methods. Finally it describes the state of the simulation experiments taken in course by us in the search to generate adaptable communication protocols between robotic building elements.

1 INTRODUCTION

A DEMAND FOR ADAPTABILITY IN ARCHITECTURE

We live in an ever-changing environment where variations occur at different paces, from slow climate changes and tectonic movements to fast volcanic eruptions and meteorite collisions; in this sense even the human race has presented itself as a rapid catalyzer for these environmental modifications. Formerly architecture was thought of as a response to present conditions, represented by the need to house determined activities and social functions, without taking into account environmental changes, social transformations or material developments. In the last century we have witnessed a phenomenon that has challenged this way of generating architecture; while in the past social functions and the buildings designed for them would absorb several generations nowadays we witness how numerous new social activities emerge within the time frame of a single generation, we are also observing fast changes in global climates and witnessing a race in the development for new materials and technologies. These factors add up, resulting in a demand for an increase in the adaptability of spaces. Although adaptation is a complex concept emerged from the study of living forms, when we speak of adaptable architecture we quickly picture dynamically shifting spaces and moving or responsive surfaces. We will take a few steps back from these notions and focus on what adaptability means nowadays within the design field; what could be the result of its application into the built environment and how can we approach it with the current design and material technologies.

The following work is divided in three main sections: In the first, we explain the framework of our research, getting familiar with adaptability´s concepts as well as a quick introduction to how the chemoton model works. In the second, we will address the application of these concepts within architecture and particularly how it derived into the binary simulation method proposed in this paper, finally we will describe the experiments taken in place, its results and our expectations for this type of approach.

2 LIFE AS ADAPTABLE MECHANISM

LIVING SYSTEMS

One of nature's most exciting phenomena has handled changes in its environment for millions of years with notable success, *life* has proven to align effective mechanisms for adaptation towards a multiplicity of elements in a concept we now know as evolution. In the last three decades there has been a strong push trying to understand such mechanisms, we will use these scientific breakthroughs as the groundwork upon which we will define our approach on the concept of adaptability within architecture and the built environment.

A LITTLE TASTE OF THE CHEMOTON MODEL

The chemoton model developed by Tibor Gánti in 1971 chemically simplifies the mechanics of what we consider to be a living entity. In his work this structure of relationships is called *chemoton*, a chemical machine with all the fundamental properties shown by a living system. We will try to give a quick glimpse of how the chemoton structure works according to Gánti's description (Gánti 2003: 3).

A chemoton is divided into three components (Figure 1) first a *control* component that houses the genetic material, a set of instructions to build the whole system; secondly a *metabolic* element generates all the building blocks used for the construction of the three components and genetic material; finally a *membrane* forming the boundary of the system and serving as filter between the environment and the interior components of this living machine.

Although the resulting structure presents all the fundamental properties found in every living being, including *"adaptation"*, we will need to observe what challenges are presented by this type of system at its own scale to be able to transport it into a building environment.

3 CHEMOTON MODEL APPLIED TO ARCHITECTURE

THE CHALLENGES

A chemoton diagram clarifies to a great extent how a system with the correct elements and relationships could present the properties necessary for adaptation and evolution such as growth, regeneration, coupling and reproduction. However there are specific conditions that allow the development of these desirable properties. Two main issues represent big challenges in order to take advantage of such natural organisations and import the demanded *"adaptation"* property into the built environment: *material state* and *communication protocol*.

1. The chemoton is also referred to by Gánti as a fluid machine (Gánti 2003: 16), this type of mechanism takes advantage of liquid and gaseous states of matter. Within these conditions all the different alignments and interactions between compounds are allowed, thus acting as engines for permutation of different chemical reactions happening at a molecular level. Architecture and the built environment on the other hand work at a bigger scale finally consolidating into solid state components where chemical reactions are slowly modifying them and physical effects such as gravity, collisions, inertia constrain the possibilities to permutate the geometrical and mechanical relationships between the building's components.

In current academic and architecture research practice the study of robotics has entered the field to confront constraints presented from working within solid states of matter, achieving the transportation of some properties observed in "looser" or fluid states through the arrangement and actuation of different forms of transductors (servos, sensors, displays). These accomplishments have derived in CNC construction of large scale structures (Gramazio &

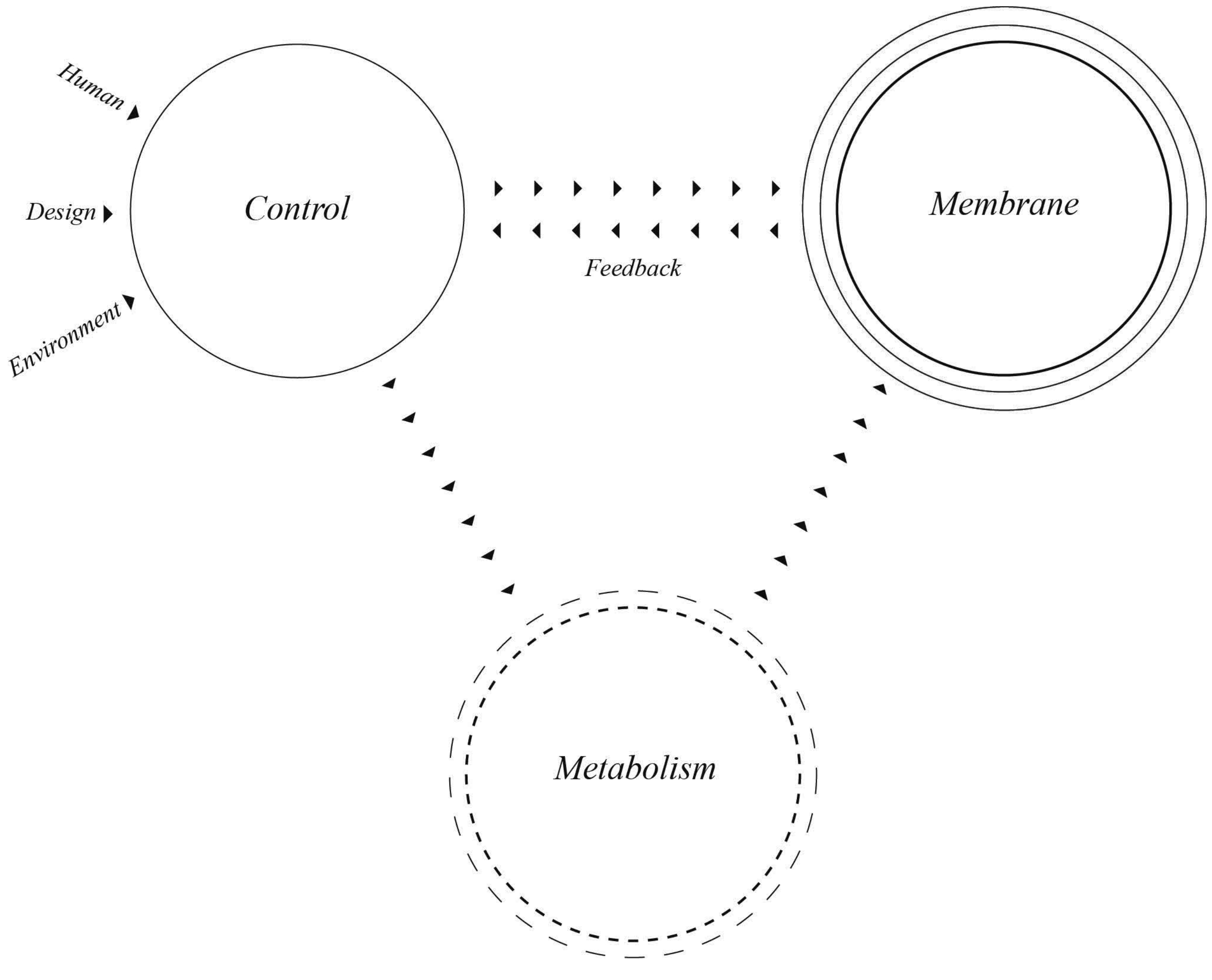
Kohler 2008), interactive spatial components (Beesley 2010), computer controlled spatial performances (Saatchi & Saatchi 2012), robotic reconfigurations and repairs (Dettwiler 2008), and four-dimensional printing (Tibbits 2012).

2. The second issue which this paper addresses is fundamental to accomplish a richer adaptability, the communication of instructions through different generations is what allows some of the most important properties for adaptation to take place. Genetic material in living beings provides a set of instructions that can be copied for reproductive purposes deveining in the capacity to replicate a whole new system with the same characteristics as the source entity. Furthermore the same genetic material can be modified throughout the systems "living" stage allowing it to mutate and produce new iterations of its predecessors deriving into an evolutionary adaptation process.

A DIGITAL STATE

From its beginnings in the past century cybernetics and robotics have used digital technology to communicate with and control robotic systems; the developments in computing languages and semiconductor technology presented the best media to approach the need of giving instructions to actuation devices. To address the issue of how communication can take place within adaptable design we will take advantage of some intrinsic properties allowed by the digital state to generate information material that can be transmitted between constructive components once a flow of energy is active within such systems. Some of these properties are: memory storage, information copying capacity, flow control, condition setting and mathematical operation functions.

Binary code constitutes the most basic language in the digital state; we will use it as a media to generate information strings that can represent the building's conditions. Furthermore it gives us the



2 Describes the overall component arrangement and the flows of information

possibility to affect these sets of instructions over time by feeding information gathered from the environment.

In sum the digital state allows us to design the rules of the system, how reactions can happen and results can be easily simulated, oriented and documented. Digital/binary is the perfect state/media to accomplish our first experiments; the resulting binary codes will translate then into the "DNA" that is embedded in robotic construction systems.

4 ADAPTABLE COMMUNICATION SYSTEM DESCRIPTION

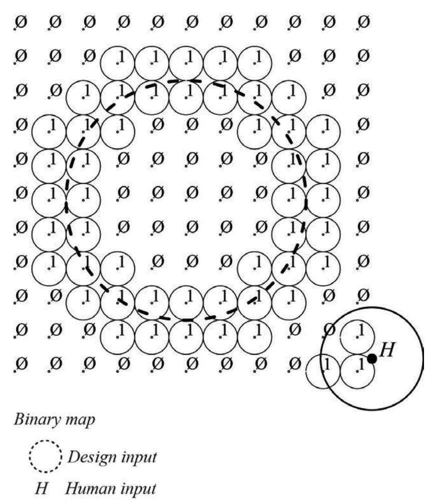
METHOD STRUCTURE

We assume that at some point each building component or construction system (walls, apertures, structural elements, slabs, et cetera) will be able, by means of robotics, to actuate and perform dynamically. This experiment also assumes that each construction system is embedded with a simple programmable control unit that allows it to react independently and receive and send digital information to other elements. The method will consist of programming each control unit with a simple set of functions that run whenever an energy flow is active through the system. The communication will use a specific protocol (in this case binary code) so the construction elements are able to react accordingly.

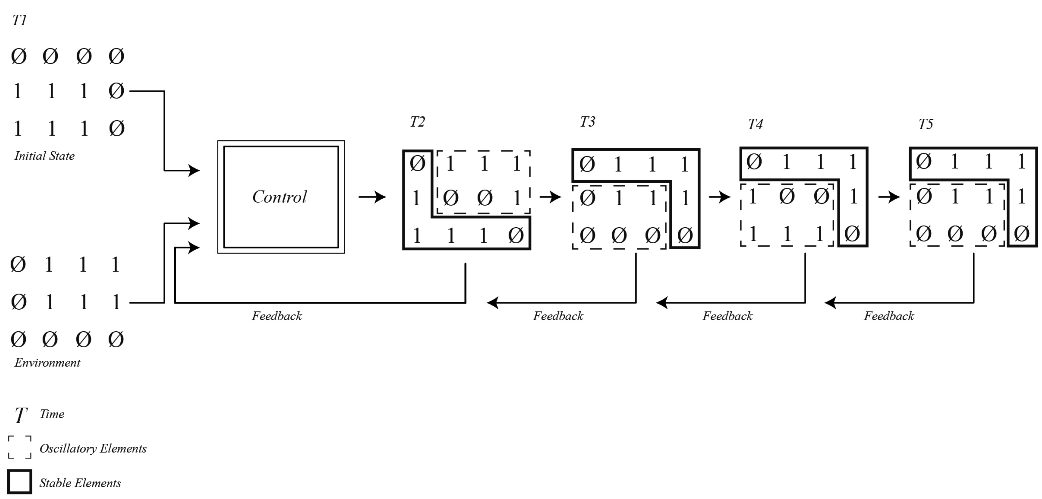
Using grasshopper and python scripting language we have created a simple diagram with the three components of a chemoton model. A control unit, a metabolic component and a membrane renderer; they are inter-connected, passing information in the form of binary strains (Figure 2).

For the purposes of these experiments we used a two-dimensional matrix to graphically understand the changes inflicted on the information strains. In Figure 3 we see a designed pattern described by a circular looking curve and a "human" input represented by a point.

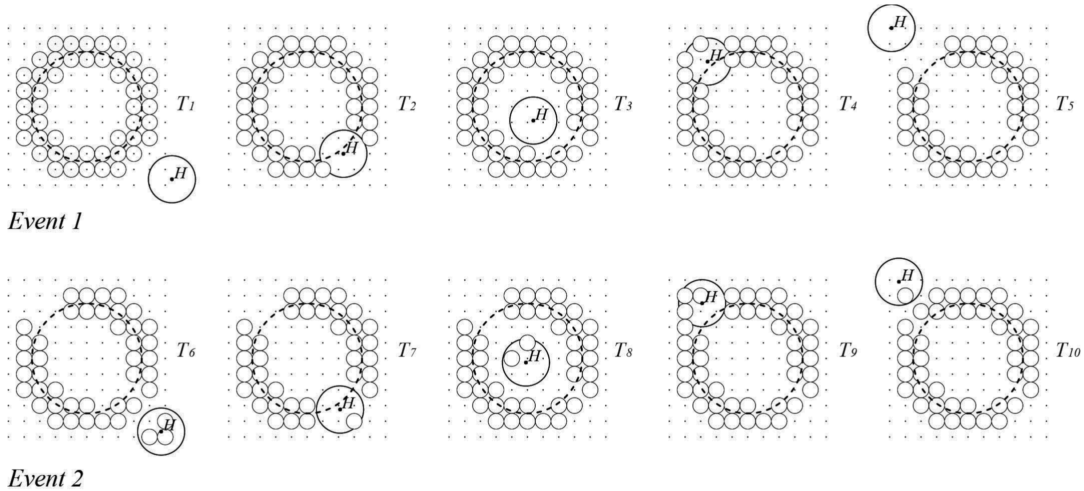
The control unit receives all the external inputs in the form of *Binary Strains (BS)* and a simple function computes the *BS* sums. The resulting *BS* has the same amount of data as the input strains, but will have a different binary configuration and is used for both the generation of the elements that get produced by the metabolic component at that specific time frame and as feedback input for the following computations. A metabolic component receives the resulting *BS* from the control unit and its function is to create objects with those instructions; a value of "0" would create a small (point-like) spherical object while a "1" would create a spherical object with a bigger radius. Finally the membrane component runs the "build" functions embedded in the objects created by the metabolic unit to graphically render the results.



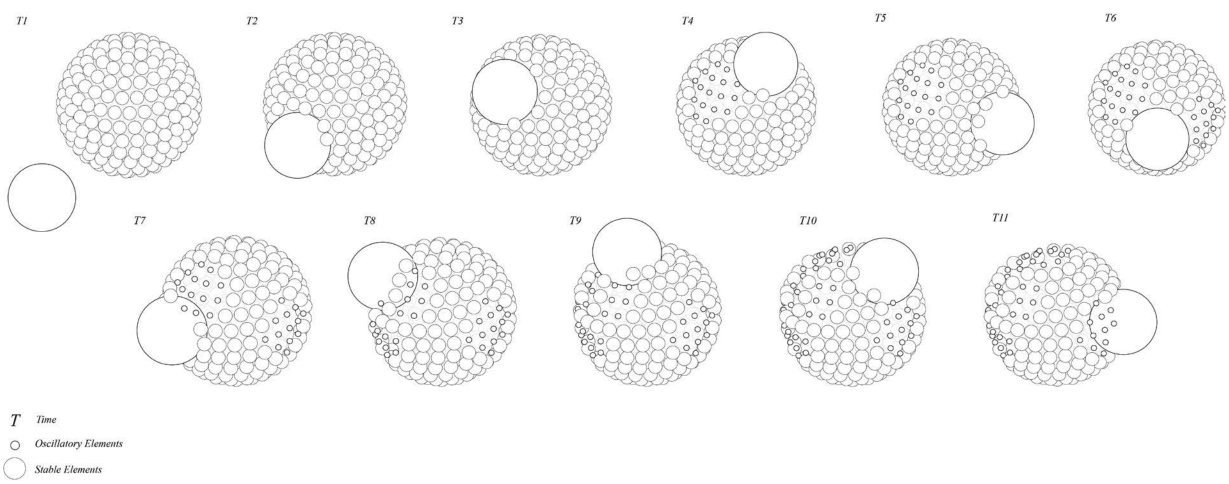
3 Graphical abstraction of the binary strain on a two-dimensional matrix



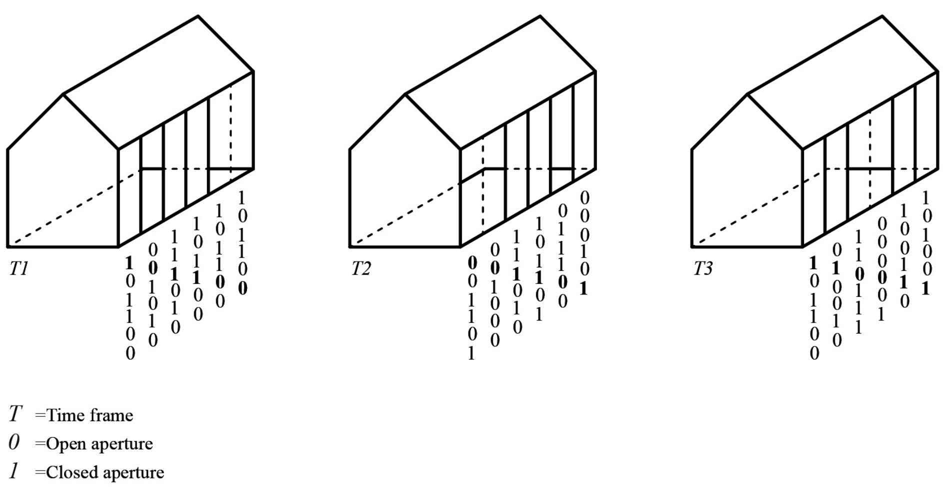
4 Simulation over time showing oscillation and stability parts of a strain



5 Describes how the system retains information after an interaction event modifying the system's behavior for a second event of similar characteristics



6 Simulation taking place in a spherical three-dimensional arrangement



7 Binary Strains embedded in BIM elements performing through time

The rules of the system are a simple set of binary additions that present autocatalytic properties: 1+1=0 : 0+0=0 : 0+1=1 : 1+0=1

We depict an example of a small matrix being added in a coupled cycle (Figure 4). We noticed there are two results that oscillate from zero to one and back within the simulations, this effect is well known in chemical reactions with feedback (Gánti 2003, 23), while some pieces of the information strain remained stable.

Lastly we gated the stable parts of the system to eliminate the noise of non-stable (oscillatory elements) and get a clearer rendering of the resulting information map.

5 CONCLUSIONS

The current state of our experiments show binary strains that get changed by the environmental events interacting with the system, thus mutating the system's "DNA" such variations within information sets will then affect future behavioral reactions. The information system (genetic material recorded in a specific building component) presents then several of the properties of an adaptable system: growth, reduction, movement, mutation and reproduction.

Although the experiment graphical abstractions depicted in the diagrams (Figures 5 and 6) try to render the binary information fingerprint as space, people as an effector point and the design as a curve or sphere, the system rules are not calibrated to achieve a specific goal yet. Hence what is achieved is the mutation of such fingerprints through time; which would represent the possibility for adaptation in the instructions of how a robotic system would behave. These instructions could potentially be included into BIM objects for the performance simulation of robotic architectural systems (Figure 7). The next questions to be addressed by this work in progress point towards the simulation of such communication interaction in multiple-agent systems, as well as the modification of the sets of binary rules.

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